

APPENDIX I – GRINDING

I1. PANEL LINE GRINDER

Table I-1. Panel Line Grinder RULA

Rapid Upper Limb Assessment (RULA)
Matamney and Corlett (1993)

Work Phase	Grind surface		Reposition body, tool		Rest		Change tool		Needle gun	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Shoulder Extension/ Flexion	mod flex	3	neut	1	neut	1	sl flx	2	mod flex	3
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	add	1	neut	0	neut	0	neut	0	add	1
Shoulder Lateral/ Medial	mod med	1	neut	0	neut	0	neut	0	mod med	1
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	neut	1	ext	2
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score: If posture mainly static (i.e. held for longer than 10 minutes) or; if action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		0		1		2

Table I-1. Panel Line Grinder RULA (continued)

Work Phase	Grind surface		Reposition body, tool		Rest		Change tool		Needle gun	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	flx	3	sl flx	2	sl flx	2	sl flx	2	flx	3
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	hyp flx	4	neut	1	neut	1	sl flx	2	hyp flx	4
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		1		0
Legs: If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; if action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		2
Total RULA Score	7		2		2		3		7	
<p>1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately</p>										

Table I-2. Panel Line Grinder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg (1995)

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the far right box.					
Rating Criterion	% Maximal Strength	Borg Scale	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	10% - 29%	3	noticeable or definite effort	2	3.0
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion	< 10%	1	0.5
= 100 x duration of all exertions (sec)	10% - 29%	2	1.0
Total observation time (sec)	30% - 49%	3	1.5
= 100 x 475 (sec)/813 (sec)	50% - 79%	4	2.0
= 58%	> or = 80%	5	3.0
Duration of Exertion Multiplier			2.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, and then dividing the number of exertions by the duration of the observation period, measured in minutes. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute	< 4	1	0.5
= number of exertions	4 - 8	2	1.0
total observation time (min)	9 - 14	3	1.5
= 44/14 = 3.2, but task is static,	15 - 19	4	2.0
set multiplier to 3.0	> or = 20	5	3.0
Efforts per Minute Multiplier			3.0

Table I-2. Panel Line Grinder Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
Rating Criterion	Wrist Extension	Wrist Flexion	Ulnar Deviation	Perceived Posture	Rating	Multiplier
Very Good	0 – 10 degrees	0 – 5 degrees	0 – 10 degrees	perfectly neutral	1	1.0
Good	11 – 25 degrees	6 – 15 degrees	11 – 15 degrees	near neutral	2	1.0
Fair	26 – 40 degrees	16 – 30 degrees	16 – 20 degrees	non-neutral (*estimated, based on RULAs done)	3	1.5
Bad	41 – 55 degrees	31 – 50 degrees	21 – 25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working.				
Rating Criterion	Observed Pace/MTM Predicted Pace x 100%	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% – 90%	“taking one’s own time”	2	1.0
Fair	91% - 100%	“normal” speed of motion	3	1.0
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

6. Duration of Task per Day: Either measured or obtained from plant personnel			
Worksheet:			
Duration of Task per Day (hrs)	Rating Criterion	Rating	Multiplier
= duration of task (hrs) +	< or = 1 hr	1	0.25
duration of task (hrs) + ...	1 – 2 hrs	2	0.50
	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 4- 8 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

Table I-2. Panel Line Grinder Strain Index (continued)

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
6.0 X	2.0 X	3.0 X	1.5 X	1.0 X	1.00		<u>54</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5 – 30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31 – 60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE; and
- SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table I-3. Panel Line Grinder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

* “No” responses are indicative of conditions associated with the risk of CTD’s

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker’s hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without “clothes wringing” motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool’s handle between 5 and 7 cm (2-2 3/4 inches)?		Y (grinder)
6.3 Is the handle of the tool made from material other than metal?	N	Y
6.4 Is the weight of the tool below 4 kg (9lbs)?	N	
6.5 Is the tool suspended?	N	
TOTAL	15 (68%)	7 (32%)

Table I-4. Panel Line Grinders OWAS

OWAS: OVAKO Work Analysis System
 Louhevaara and Suurnäkki (1992)

Work Phase	Grind surface	Move body, tool	Rest	Change tool	Needle gun
TOTAL Combination Posture Score	3	1	1	2	3
Common Posture Combinations (collapsed across work phases)					
Back	2	1	2		
Arms	2	1	1		
Legs	4	7	7		
Posture Repetition (% of working time)	58	37	8		
Back % of Working Time Score	2	1	1		
Arms % of Working Time Score	2	1	1		
Legs % of Working Time Score	3	1	1		
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately					

Table I-4. Panel Line Grinder OWAS (continued)

Work Phase	Grind surface	Move body, tool	Rest	Change tool	Needle gun
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	2
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	7	7	7	4
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	1	1	1	1
Phase Repetition					
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	55	29	4	8	3

Table I-5. Panel Line Grinder PLIBEL

PLIBEL Checklist
Kemmlert (1995)

Section I: Musculoskeletal Risk Factors					
Methods of Application:					
1) Find the injured body region, answer yes or no to corresponding questions					
2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table I-5. Panel Line Grinder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table I-5. Panel Line Grinder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	7	3	3	11
PERCENTAGE	53.8	63.6	37.5	37.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying)					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

12. SHIPFITTER GRINDING

Table I-6. Shipfitter Grinding RULA

Rapid Upper Limb Assessment (RULA)
Matamney and Corlett (1993)

Work Phase	Grind surface		Reposition body		Reposition adjust tool		Inspect, rest		Torch cut		Deslag	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flex	3	sl flex	2	mod flex	3	mod flex	3
Shoulder is Raised (+1)		1		0		1		1		1		0
Upper Arm Abducted (+1)		0		0		0		0		1		0
Arm supported, leaning (-1)		-1		-1		-1		-1		-1		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	add	1	neut	0	neut	0	neut	0	mod abd	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	lat	1	lat	1
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	neut	1	ext	2	flx	2
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		2		1

Table I-6. Shipfitter Grinding RULA (continued)

Work Phase	Grind surface		Reposition body		Reposition adjust tool		Inspect, rest		Torch cut		Deslag	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	ext	4	neut	1	ext	4	ext	4	ext	4	sl flx	2
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	sl flx	2
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs: If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+1)		1		0		0		0		1		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		1
Total RULA Score	6		2		3		3		6		4	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately												

Table I-7. Shipfitter Grinding Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the far right box.					
Rating Criterion	% Maximal Strength	Borg Scale	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	10% - 29%	3	noticeable or definite effort	2	3.0
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion = $100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ = $100 \times \frac{1167 \text{ (sec)}}{1499 \text{ (sec)}}$ = 78%	< 10%	1	0.5
	10% - 29%	2	1.0
	30% - 49%	3	1.5
	50% - 79%	4	2.0
	> or = 80%	5	3.0
Duration of Exertion Multiplier			2.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, and then dividing the number of exertions by the duration of the observation period, measured in minutes. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute = $\frac{\text{number of exertions}}{\text{total observation time (min)}}$ = nearly static tasks, set multiplier to 3.0	< 4	1	0.5
	4 - 8	2	1.0
	9 - 14	3	1.5
	15 - 19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			3.0

Table I-7. Shipfitter Grinding Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
Rating Criterion	Wrist Extension	Wrist Flexion	Ulnar Deviation	Perceived Posture	Rating	Multiplier
Very Good	0 – 10 degrees	0 – 5 degrees	0 – 10 degrees	perfectly neutral	1	1.0
Good	11 – 25 degrees	6 – 15 degrees	11 – 15 degrees	near neutral	2	1.0
Fair	26 – 40 degrees	16 – 30 degrees	16 – 20 degrees	non-neutral (*estimated, based on RULAs done)	3	1.5
Bad	41 – 55 degrees	31 – 50 degrees	21 – 25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working.				
Rating Criterion	Observed Pace/MTM Predicted Pace x 100%	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% – 90%	“taking one’s own time”	2	1.0
Fair	91% - 100%	“normal” speed of motion	3	1.0
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

6. Duration of Task per Day: Either measured or obtained from plant personnel			
Worksheet:			
Duration of Task per Day (hrs)	Rating Criterion	Rating	Multiplier
= duration of task (hrs) +	< or = 1 hr	1	0.25
duration of task (hrs) + ...	1 – 2 hrs	2	0.50
	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 2 - 4 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			0.75

Table I-7. Shipfitter Grinding Strain Index (continued)

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
6.0 X	2.0 X	3.0 X	1.5 X	1.0 X	0.75		<u>40.5</u>

- SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
 - SI Score of between 5 – 30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
 - SI Score of between 31 – 60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE; and
 - SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table I-8. Shipfitter Grinding UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

* “No” responses are indicative of conditions associated with the risk of CTD’s

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker’s hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without “clothes wringing” motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N (elec. grind.)	
6.2 Is the span of the tool’s handle between 5 and 7 cm (2-2 3/4 inches)?	N (elec. grind.)	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	15 (68.1%)	7 (31.8%)

Table I-9. Shipfitter Grinding OWAS

OWAS: OVAKO Work Analysis System
 Louhevaara and Suurnäkki (1992)

Work Phase	Grind surface	Move body	Move, adjust tool	Inspect, rest	Torch cut	Deslag
TOTAL Combination Posture Score	3	1	2	2	3	2
Common Posture Combinations (collapsed across work phases)						
Back	2	2	1			
Arms	3	1	1			
Legs	1	1	7			
Posture Repetition (% of working time)	35	31	24			
Back % of Working Time Score	2	2	1			
Arms % of Working Time Score	2	1	1			
Legs % of Working Time Score	1	1	1			
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately						

Table I-9. Shipfitter Grinding OWAS (continued)

Work Phase	Grind surface	Move body	Move, adjust tool	Inspect, rest	Torch cut	Deslag
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	2	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	1	1	1	3	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	7	1	1	1	1
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	1	1	1	2	1
Phase Repetition						
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	11	24	18	12	24	1

Table I-10. Shipfitter Grinding PLIBEL

PLIBEL Checklist
Kemmlert (1995)

Section I: Musculoskeletal Risk Factors					
Methods of Application:					
1) Find the injured body region, answer yes or no to corresponding questions					
2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table I-10. Shipfitter Grinding PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table I-10. Shipfitter Grinding PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	8	3	3	9
PERCENTAGE	50.0	72.7	37.5	37.5	42.9
Section II: Environmental / Organizational Risk Factors (Modifying)					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	6				
PERCENTAGE	60.0				

13. TANK GRINDER

Table I-11. Tank Grinder RULA

Rapid Upper Limb Assessment (RULA)
Matamney and Corlett (1993)

Work Phase	Grinding; disc (5 in)		Tool Change		Pad Change		Grinding; disc (3in)		Wire Brush		Needle Gun	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Shoulder Extension/ Flexion	mod flex	3	neut	1	neut	1	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		1		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	neut	2	flx	2	neut	2	flx	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	add	1	add	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	neut	0	ulnar	1	rad	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score: If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2

Table I-11. Tank Grinder RULA (continued)

Work Phase	Grinding; disc (5 in)		Tool Change		Pad Change		Grinding; disc (3in)		Wire Brush		Needle Gun	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	neut	1	neut	1	neut	1	ext	4	ext	4	neut	1
Neck Twist (+1)		0		0		0		1		0		0
Neck Side-Bent (+1)		0		0		0		1		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		1		0		0
Legs: If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; if action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2
Total RULA Score	6		3		3		7		7		5	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately												

Table I-12. Tank Grinder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg (1995)

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the far right box.					
Rating Criterion	% Maximal Strength	Borg Scale	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	10% - 29%	3	noticeable or definite effort	2	3.0
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion	< 10%	1	0.5
= 100 x duration of all exertions (sec)	10% - 29%	2	1.0
Total observation time (sec)	30% - 49%	3	1.5
= 100 x 2726 (sec)/2988 (sec)	50% - 79%	4	2.0
= 91%	> or = 80%	5	3.0
Duration of Exertion Multiplier			3.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, and then dividing the number of exertions by the duration of the observation period, measured in minutes. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute	< 4	1	0.5
= number of exertions	4 - 8	2	1.0
total observation time (min)	9 - 14	3	1.5
= task nearly static,	15 - 19	4	2.0
set multiplier to 3.0	> or = 20	5	3.0
Efforts per Minute Multiplier			3.0

Table I-12. Tank Grinder Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
Rating Criterion	Wrist Extension	Wrist Flexion	Ulnar Deviation	Perceived Posture	Rating	Multiplier
Very Good	0 – 10 degrees	0 – 5 degrees	0 – 10 degrees	perfectly neutral	1	1.0
Good	11 – 25 degrees	6 – 15 degrees	11 – 15 degrees	near neutral	2	1.0
Fair	26 – 40 degrees	16 – 30 degrees	16 – 20 degrees	non-neutral (*estimated, based on RULAs done)	3	1.5
Bad	41 – 55 degrees	31 – 50 degrees	21 – 25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working.				
Rating Criterion	Observed Pace/MTM Predicted Pace x 100%	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% – 90%	“taking one’s own time”	2	1.0
Fair	91% - 100%	“normal” speed of motion	3	1.0
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

6. Duration of Task per Day: Either measured or obtained from plant personnel			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs)	< or = 1 hr	1	0.25
= duration of task (hrs) +	1 – 2 hrs	2	0.50
duration of task (hrs) + ...	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 2- 4 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			0.75

Table I-12. Tank Grinder Strain Index (continued)

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
6.0 X	3.0 X	3.0 X	1.5 X	1.0 X	0.75		<u>60.8</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5 – 30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31 – 60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE; and
- SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table I-13. Shipboard Tank Grinder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

* “No” responses are indicative of conditions associated with the risk of CTD’s

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker’s hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without “clothes wringing” motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool’s handle between 5 and 7 cm (2-2 3/4 inches)?		Y (grinder)
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	14 (64%)	8 (36%)

Table I-14. Tank Grinder OWAS

OWAS: OVAKO Work Analysis System
 Louhevaara and Suurnäkki (1992)

Work Phase	Grinding disc (5 in)	Tool Change	Pad Change	Grinding disc (3in)	Wire Brush	Needle Gun
TOTAL Combination Posture Score	2	1	1	2	2	2
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2	1		
Arms	2	1	1	1		
Legs	4	1	6	4		
Posture Repetition (% of working time)	48	14	20	9		
Back % of Working Time Score	1	1	1	1		
Arms % of Working Time Score	2	1	1	1		
Legs % of Working Time Score	2	1	1	1		
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately						

Table I-14. Tank Grinder OWAS (continued)

Work Phase	Grinding disc (5 in)	Tool Change	Pad Change	Grinding disc (3in)	Wire Brush	Needle Gun
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	1	1	6	6	4
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	1	1	2	2	2
Phase Repetition						
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	48	7	7	8	12	9

Table I-15. Tank Grinder PLIBEL

PLIBEL Checklist
Kemmlert (1995)

Section I: Musculoskeletal Risk Factors					
Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table I-15. Tank Grinder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table I-15. Tank Grinder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	9	5	5	11
PERCENTAGE	53.8	81.8	62.5	62.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying)					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	6				
PERCENTAGE	60.0				